

TeV- and MeV-physics out of an $SU(2) \times U(1) \times U(1)$ model

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The standard electroweak interaction is here re-assessed to accomodate, in a particular situation, the recent discussion of a possible fifth force mediated by the 17-MeV X-boson associated to the electron-positron emission in a transition of the Berilium-8 to its ground state. The model we present here is based on an $SU_L(2) \times U_R(1)_J \times U(1)_K$ -symmetry that yields a new massive neutral boson, an extra massive charged fermion and an additional neutral Higgs particle, which stems from the extra Higgs field present along with the usual doublet responsible for the electroweak breaking and the masses of W^\pm and Z^0 . Yukawa interactions are also introduced involving the two scalar fields to give mass to the leptons and the new fermion of the model. The vacuum expectation values of the scalars fix up two independent energy scales. One of them is the well-known electroweak scale, 246 GeV, whereas the other one is set up by adopting the uncertainty on the measurement of the Z^0 -mass.

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The understanding of a new physics beyond the Standard Model (SM) has been a challenge for the actual science. The results of experiments from LHC, ATLAS and CMS Collaboration have pointed the being of new particles in a scenario of a possible Fifth fundamental interaction [1, 2]. The study of pp collisions at a center-of-mass energy scale of $\sqrt{s} = 8$ TeV has revealed the being of heavy Bosons W' and Z' [3]. It can indicate the emergence of a new Physics at the TeV-scale. The model is so based on the gauge symmetry $SU_L(2) \times SU_R(2) \times U(1)_{B-L}$ [4], in which another Higgs must be needed to explain the heavy mass of Bosons at the range TeV-scale.

Recently, in another experimental context, anomalies of the excited state of 8Be^* to its ground state has revealed the being of a new neutral Boson X through the decay $8\text{Be}^* \rightarrow 8\text{Be} + X$ [6]. Immediately the Boson X decays in electron-positron pair $X \rightarrow e^+ + e^-$. It has a vector nature like the photon, but it must have a mass of approximately $M_X = 17$ MeV. Certainly, the being of new Boson may lead to the emergence of a Fifth fundamental interaction in the Nature. There is also in the literature a great deal of interest on then activity related to the phenomenology of hidden sector para-photons [9–11].

Based on the model built up to describe the hidden sector para-photon, our proposal in this contribution is set up a gauge model with a $SU_L(2) \times U_R(1)_J \times U(1)_K$ symmetry group that is twofold, according to the symmetry-breaking pattern. The Higgs sector is a doublet and, as we will see, there can occur two situations : the extra Higgs breaks the extra symmetry $U(1)_K$ above or below

the 246 GeV electroweak scale. These two possibilities open up new scenarios that may accommodate the extra Higgs and its associated extra gauge Boson in different scales : MeV-, GeV- and TeV-scales, according to the choice of the three parameters.

The sector of fermions is defined by the Lagrangian :

$$\mathcal{L}_{\text{leptons}-\zeta} = \bar{\Psi}_L i \not{D} \Psi_L + \bar{\ell}_R i \not{D} \ell_R + \bar{\zeta} i \not{D} \zeta, \quad (1)$$

where we have introduced the non-chiral Fermion ζ associated to $U(1)_K$ group, and the notation ℓ indicates the Leptons of the SM, *i. e.*, $\ell = (e, \mu, \tau)$. The covariant derivatives acting on fermions are defined in the following way

$$\begin{aligned} D_\mu \Psi_L &= \left(\partial_\mu + i g A_\mu^a \frac{\sigma^a}{2} + i J_L g' B_\mu + i K_L g'' C_\mu \right) \Psi_L, \\ D_\mu \ell_R &= \left(\partial_\mu + i J_R g' B_\mu + i K_R g'' C_\mu \right) \ell_R, \\ D_\mu \zeta &= \left(\partial_\mu + i J_\zeta g' B_\mu + i K_\zeta g'' C_\mu \right) \zeta, \end{aligned} \quad (2)$$

in which $A^{\mu a} = (A^{\mu 1}, A^{\mu 2}, A^{\mu 3})$ are the gauge fields of $SU_L(2)$, B^μ is the abelian gauge field of $U_R(1)_J$, and C^μ the similar one to $U(1)_K$. Here the symbol J stands for the generators of $U_R(1)_J$, whereas K represents the generators of $U(1)_K$, and the Pauli matrices $\frac{\sigma^a}{2}$ ($a = 1, 2, 3$). In (2), g , g' and g'' are dimensionless gauge couplings.

The Ψ_L is defined as a doublet of left-handed neutrinos/leptons that turn in the fundamental representation of $SU_L(2)$, ℓ_R and ζ are singlets of Abelian sectors. In the sector gauge fields, the field strength tensors are defined by

$$\begin{aligned} F_{\mu\nu} &= \partial_\mu A_\nu - \partial_\nu A_\mu + i g [A_\mu, A_\nu], \\ B_{\mu\nu} &= \partial_\mu B_\nu - \partial_\nu B_\mu, \\ C_{\mu\nu} &= \partial_\mu C_\nu - \partial_\nu C_\mu, \end{aligned} \quad (3)$$

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The sector of gauge bosons is described by the Lagrangian

$$\mathcal{L}_{Gauge} = -\frac{1}{2} \text{tr} (F_{\mu\nu}^2) - \frac{1}{4} B_{\mu\nu}^2 - \frac{1}{4} C_{\mu\nu}^2 - \frac{\chi}{2} B_{\mu\nu} C^{\mu\nu}, \quad (4)$$

where χ is a real parameter that mixes the abelian gauge fields of the subgroup $U_R(1)_J \times U(1)_K$. In general, it has the estimative $10^{-3} < \chi < 10^{-6}$ for models involving hidden photons of the Dark Matter [11].

The Higgs sector is introduced by the Lagrangian

$$\begin{aligned} \mathcal{L}_{Higgs} = & (D_\mu \Xi)^\dagger D^\mu \Xi - \mu_\Xi^2 (\Xi^\dagger \Xi) - \lambda_\Xi (\Xi^\dagger \Xi)^2 \\ & + (D_\mu \Phi)^\dagger D^\mu \Phi - \mu_\Phi^2 (\Phi^\dagger \Phi) - \lambda_\Phi (\Phi^\dagger \Phi)^2 \\ & - \lambda_{\Xi\Phi} (\Xi^\dagger \Xi) (\Phi^\dagger \Phi) \\ & - x_\ell \bar{\zeta}_L \Xi \ell_R - x_\ell^* \bar{\ell}_R \Xi^\dagger \zeta_L \\ & - y_\ell \bar{\Psi}_L \Phi \ell_R - y_\ell^* \bar{\ell}_R \Phi^\dagger \Psi_L \\ & - z_\ell \bar{\Psi}_L \Phi \zeta_R - z_\ell^* \bar{\zeta}_R \Phi^\dagger \Psi_L, \end{aligned} \quad (5)$$

where μ_Ξ , μ_Φ , λ_Ξ , λ_Φ and $\lambda_{\Xi\Phi}$ are real parameters, and $\{x_\ell, y_\ell, z_\ell\}$ are Yukawa complex coupling constants that yield the masses for the fermions of the model. The covariant derivative of (5) acts on the Ξ -Higgs as follows :

$$\begin{aligned} D_\mu \Xi &= \left(\partial_\mu + i J_\Xi g' B_\mu + i K_\Xi g'' C_\mu \right) \Xi, \\ D_\mu \Phi &= \left(\partial_\mu + i g A_\mu^a \frac{\sigma^a}{2} + i g' J_\Phi B_\mu \right) \Phi. \end{aligned} \quad (6)$$

The Ξ -field is defined as a scalar singlet that has the transformation under symmetry group $U_R(1)_J \times U(1)_K$, while Φ is a doublet in the fundamental representation of $SU_L(2)$. The Yukawa interactions are gauge invariant if we impose that the relations :

$$\begin{aligned} -J_{\zeta_L} + J_\Xi + J_R &= 0 \\ -K_{\zeta_L} + K_\Xi + K_R &= 0 \\ -J_L + J_\Phi + J_R &= 0 \\ -J_L + J_\Phi + J_{\zeta_R} &= 0. \end{aligned} \quad (7)$$

The minimal value of the Higgs potential is obtained by the non-trivial VEV $\langle \Xi \rangle_0 = u/\sqrt{2}$, in which u is defined by $u := \sqrt{-\frac{\mu_\Xi^2}{\lambda_\Xi}}$, when $\mu_\Xi^2 < 0$. For the Φ -Higgs, the VEV scale is chosen as $\langle \Phi \rangle_0 = \begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix}$, where $v := \sqrt{-\frac{\mu_\Phi^2}{\lambda_\Phi}}$. We choose the parametrization of the Ξ - and Φ -complex fields in the unitary gauge as

$$\Xi(x) = \left(\frac{u + F(x)}{\sqrt{2}} \right), \quad \Phi(x) = \begin{pmatrix} v + H(x) \\ 0 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \quad (8)$$

where F and H are real functions.

Under these conditions, the Higgs potential is plotted below. We observe the four peaks that represent the vacuum states of the scalars fields.

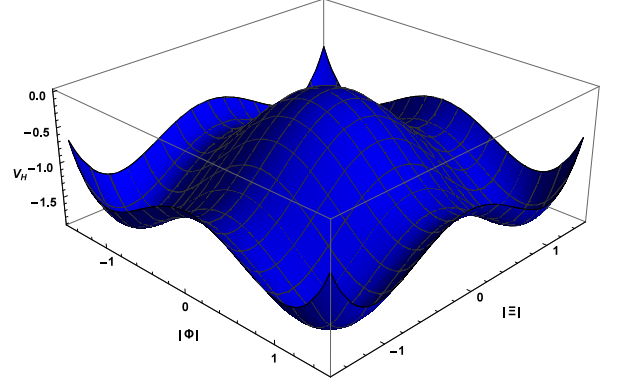


FIG. 1: The Higgs potential as function of the variables $|\Xi|$ and $|\Phi|$ for $\mu_\Xi < 0$, $\mu_\Phi < 0$ and when $\lambda_\Xi > 0$, $\lambda_\Phi > 0$ and $\lambda_{\Xi\Phi} > 0$. The degenerated vacuum of the Higgs fields are illustrated by the four down peaks.

The VEVs- $\{u, v\}$ define two scales for the breaking the gauge symmetry, so that after the SSB, we obtain the Lagrangian

$$\begin{aligned} \mathcal{L}_{Gauge} = & -\frac{1}{2} W_{\mu\nu}^+ W^{\mu\nu-} + \frac{g^2 v^2}{4} W_\mu^+ W^{\mu-} \\ & -\frac{1}{4} (\partial_\mu A_\nu^3 - \partial_\nu A_\mu^3)^2 \\ & + \frac{1}{2} \frac{v^2}{4} (g_Y X_\mu - g_Y Y_\mu + g A_\mu^3)^2 \\ & -\frac{1}{4} B_{\mu\nu}^2 - \frac{1}{4} C_{\mu\nu}^2 - \frac{\chi}{2} B_{\mu\nu} C^{\mu\nu} \\ & + \frac{u^2}{2} \left(g' B^\mu - g'' C^\mu \right)^2, \end{aligned} \quad (9)$$

where for convenience, we have chosen $J_\Xi = -K_\Xi = +1$. This sector introduces the $SO(2)$ -transformations in (9) to eliminate the mixed terms

$$\begin{aligned} C_\mu &= \frac{1}{\sqrt{2}} X_\mu + \frac{1}{\sqrt{2}} Y_\mu \\ B_\mu &= -\frac{1}{\sqrt{2}} X_\mu + \frac{1}{\sqrt{2}} Y_\mu, \\ A_\mu^3 &= \cos \theta_W Z_\mu + \sin \theta_W A_\mu \\ Y_\mu &= -\sin \theta_W Z_\mu + \cos \theta_W A_\mu, \end{aligned} \quad (10)$$

where θ_W is the Weinberg's angle, that satisfies the relation

$$e = g \sin \theta_W = g_Y \cos \theta_W. \quad (11)$$

The coupling constant g_Y associated with the hypercharge generator $Y = J + K$ of the left or right sectors, become, after the SSBs $g_Y \sqrt{2-2\chi} = g' = g''$. Naturally, the electric charge satisfies the relation $Q_{em} = I_3 + Y$, where $I_3 = \frac{\sigma_3}{2}$. All charges are determined as

showed in the table below :

Fields & particles	Q_{em}	I^3	Y	J	K
lepton-left	-1	-1/2	-1/2	-1/2	0
lepton-right	-1	0	-1	-1	0
neutrino-left	0	+1/2	-1/2	-1/2	0
neutrino-right	0	0	0	0	0
left- ζ	-1	0	-1	0	-1
right- ζ	-1	0	-1	-1	0
W^\pm bosons	± 1	± 1	0	0	0
neutral bosons	0	0	0	0	0
Higgs - Ξ	0	0	0	+1	-1
Higgs - Φ	0	-1/2	+1/2	+1/2	0

As in the usual case, the mass of W^\pm is $m_{W^\pm} = \frac{1}{2} g v$, and mass of X^μ is identified in terms of VEV scale- u as $m_X = 2 g_Y u$. The sector of masses of the neutral bosons Z^0 and X^μ can be written in the matrix form

$$\mathcal{L}_{mass}(Z-X) = \frac{1}{2} (V^\mu)^t \eta_{\mu\nu} M_{Z-X}^2 V^\nu, \quad (12)$$

where $(V^\mu)^t = (Z^\mu \ X^\mu)$ and M_{Z-X}^2 is the mass matrix below :

$$M_{Z-X}^2 = \begin{pmatrix} m_Z^2 & \frac{m_Z m_X}{4x} \\ \frac{m_Z m_X}{4x} & m_X^2 + \frac{m_X^2}{16x^2} \end{pmatrix}. \quad (13)$$

Here, the dimensionless parameter x has been defined by $x := u/v$, and m_Z is the mass of Z^0 at the tree level approximation. The scale v is defined by the Fermi's constant by $v = (\sqrt{2} G_F)^{-1/2} \simeq 246$ GeV, and considering that $\sin^2 \theta_W \simeq 0.23$, the parametrization (11) gives us the masses of W^\pm and Z^0

$$m_{W^\pm} = \frac{37 \text{ GeV}}{|\sin \theta_W|} \simeq 77 \text{ GeV},$$

$$m_{Z^0} \simeq 89 \text{ GeV} \left(1 - \frac{v^2}{32 u^2} \right). \quad (14)$$

To estimate the mass of the hidden boson X^μ , we use the experimental value $m_{Z^0} = 91.1876 \pm 0.0021$ GeV, in which the uncertainty measure and fixes the scale at $u \simeq 8.9$ TeV. Therefore the mass of X^μ is around the value

$$m_X \simeq 6 \text{ TeV}. \quad (15)$$

The massive sector of the Higgs fields $F-H$ after the SSBs is given by

$$\mathcal{L}_{mass}^{F-H} = \frac{1}{2} V^t M_{F-H}^2 V, \quad (16)$$

where $V^t = (F \ H)$, and M_{F-H}^2 is the mass matrix as follows

$$M_{F-H}^2 = \begin{pmatrix} 2\lambda_\Xi u^2 + \frac{1}{2}\lambda_{\Xi\Phi} v^2 & 2\lambda_{\Xi\Phi} u v \\ 2\lambda_{\Xi\Phi} u v & 2\lambda_\Phi v^2 + \frac{1}{2}\lambda_{\Xi\Phi} u^2 \end{pmatrix}. \quad (17)$$

When $u \gg v$, the eigenvalues of (17) are

$$M_H \simeq \sqrt{2\lambda_\Phi} v^2 \left(1 + \frac{u^2}{4v^2} \frac{\lambda_{\Xi\Phi}}{\lambda_\Phi} \right),$$

$$M_F \simeq \sqrt{2\lambda_\Xi} u^2 \left(1 + \frac{v^2}{8u^2} \frac{\lambda_{\Xi\Phi}}{\lambda_\Xi} \right). \quad (18)$$

The experimental result $M_H = 125.7 \pm 0.4$ GeV fixes the coupling constant $\lambda_\Phi \simeq 0.13$. The coupling constant $\lambda_{\Xi\Phi}$ can be consistently fixed by taking the uncertainty in the H -Higgs mass, which is 0.4 GeV. It turns out that $\lambda_{\Xi\Phi} \sim 10^{-6}$. If we adopt that $0.01 < \lambda_\Xi < 0.09$, the mass of Higgs- F is in the range

$$280 \text{ GeV} < M_F < 830 \text{ GeV}. \quad (19)$$

The sector of leptons and fermion- ζ acquires mass term thanks to Yukawa interactions. The mass matrix can be cast into the form

$$\mathcal{L}_{mass-\ell-\zeta} = \bar{\xi} M_{\ell-\zeta} \xi, \quad (20)$$

in which $\xi^t = (\ell \ \zeta)^t$, and $M_{\ell-\zeta}$ is the square matrix

$$M_{\ell-\zeta} = \begin{pmatrix} \frac{|y_\ell|v}{\sqrt{2}} \mathbb{1} & \frac{|x_\ell|uL+|z_\ell|vR}{\sqrt{2}} \\ \frac{|x_\ell|uR+|z_\ell|vL}{\sqrt{2}} & 0 \end{pmatrix}. \quad (21)$$

Here we write the constant couplings in terms of global phases that can be absorbed in the fields, and R and L are the Right and Left projectors. The fermion matrix can be diagonalized by the unitary transformation in which the masses are given by

$$m_\ell \simeq \frac{|y_\ell|v}{\sqrt{2}}, \quad m_\zeta \simeq \frac{|g_\zeta|u}{\sqrt{2}}, \quad (22)$$

where $|g_\zeta|$ is the constant coupling extremely weak in relation to $|y_\ell|$

$$|g_\zeta| := \sum_{\ell=e,\mu,\tau} \frac{|x_\ell||z_\ell|}{|y_\ell|}. \quad (23)$$

Since $|x_\ell|$ and $|z_\ell|$ are coupling constants of Yukawa interactions involving the ζ -fermion and leptons left or right components, we consider it to be the same order, that is, $|x_\ell| \simeq |z_\ell|$. Thus if we use a mass of order $m_\zeta = 1$ TeV for the Fermion- ζ , we obtain $g_\zeta \simeq 0.15$, and the new Yukawa constants coupling are estimated as

$$|x_e| \simeq 1.6 \times 10^{-5}, \quad |x_\mu| \simeq 3 \times 10^{-2}, \quad |x_\tau| \simeq 0.55. \quad (24)$$

Our result for the X -boson mass, around 6 TeV, points to the possibility of existence of such a heavy particle above the expected Z' -mass, between 3.5 TeV and 4.5 TeV [5]. We rely on an Abelian factor to get our X^μ -boson, whereas Z' is associated with an $SU(2)$ subgroup. We are actually saying that we expect another neutral gauge boson, which is not to be identified as Z' .

In contrast to the previous case, we analyze the SSBs when $u \ll v$. This sets a SSB at a lower scale u with respect to $v = 246$ GeV of the EW model. To this end, we restart from the original symmetry $SU_L(2) \times U_R(1)_J \times U(1)_K$, but firstly, we couple the Higgs sector of EW model as it was proposed in (5). After this SSB, we obtain the final symmetry breaking pattern :

$$\begin{aligned} SU_L(2) \times U_R(1)_J \times U(1)_K &\xrightarrow{v} \\ U(1)_G \times U(1)_K &\xrightarrow{u} U(1)_{em}, \end{aligned} \quad (25)$$

where the group $U(1)_G$ is formed by the mixing of $SU_L(2) \times U_R(1)_J$. Notice the difference with respect to the previous case, where $U_R(1)_J \times U(1)_K$ was firstly broken. The free gauge sector after this SSB is represented by the Lagrangian

$$\begin{aligned} \mathcal{L}_{Gauge} = & -\frac{1}{4} (\partial_\mu A_\nu^3 - \partial_\nu A_\mu^3)^2 - \frac{1}{4} B_{\mu\nu}^2 - \frac{1}{4} C_{\mu\nu}^2 \\ & - \frac{\chi}{2} B_{\mu\nu} C^{\mu\nu} + \frac{1}{2} \frac{v^2}{4} \left(g' B^\mu - g A^{\mu 3} \right)^2. \end{aligned} \quad (26)$$

Now to diagonalize the mixed term $A^{\mu 3} - B^\mu$ in (26), we introduce the orthogonal transformation

$$\begin{aligned} A_\mu^3 &= \cos \theta_W Z_\mu + \sin \theta_W G_\mu \\ B_\mu &= -\sin \theta_W Z_\mu + \cos \theta_W G_\mu, \\ C_\mu &= \frac{1}{\sqrt{2}} X_\mu + \frac{1}{\sqrt{2}} A_\mu \\ G_\mu &= -\frac{1}{\sqrt{2}} X_\mu + \frac{1}{\sqrt{2}} A_\mu, \end{aligned} \quad (27)$$

where θ_W now satisfies the relation

$$e = g'' = g \sin \theta_W = g' \cos \theta_W. \quad (28)$$

So we obtain the Lagrangian into the form

$$\begin{aligned} \mathcal{L}_{Gauge} = & -\frac{1}{4} Z_{\mu\nu}^2 - \frac{1}{4} X_{\mu\nu}^2 - \frac{1}{4} A_{\mu\nu}^2 + \frac{1}{2} m_Z^2 Z_\mu^2 \\ & + \frac{\chi_W}{2} Z_{\mu\nu} X^{\mu\nu} + \frac{\chi_W}{2} Z_{\mu\nu} A^{\mu\nu} \\ & + \frac{1}{2} (m_X X^\mu + x m_Z Z^\mu)^2, \end{aligned} \quad (29)$$

where we have defined $\chi_W := \frac{\chi}{\sqrt{2}} \sin \theta_W$ and $x := 2 \sin^2 \theta_W u/v$, for short.

To eliminate the mixed term and $Z - A$, we shift the photon- A^μ and Z^0 Boson as

$$\begin{aligned} A^\mu &\mapsto \tilde{A}^\mu = A^\mu - \chi_W Z^\mu \\ Z^\mu &\mapsto \tilde{Z}^\mu = Z^\mu (1 - \chi_W^2), \end{aligned} \quad (30)$$

so the Lagrangian is reduced to the case mixed $\tilde{Z} - X$

$$\begin{aligned} \mathcal{L}_{Gauge} = & -\frac{1}{4} \tilde{Z}_{\mu\nu}^2 - \frac{1}{4} X_{\mu\nu}^2 + \frac{\chi_W}{2} \tilde{Z}_{\mu\nu} X^{\mu\nu} \\ & + \frac{1}{2} \tilde{m}_Z^2 \tilde{Z}_\mu^2 + \frac{1}{2} (m_X X^\mu + x \tilde{m}_Z \tilde{Z}^\mu)^2. \end{aligned} \quad (31)$$

where \tilde{m}_Z and χ_W are defined by

$$\tilde{m}_Z \simeq m_Z \left(1 + \frac{\chi_W^2}{2} \right). \quad (32)$$

The problem is so reduced to 2×2 diagonalization of the mixing $\tilde{Z} - X$. The Lagrangian involving \tilde{Z}^μ and X^μ is written into the matrix form

$$\mathcal{L}_{Gauge}^{\tilde{Z}-X} = \frac{1}{2} (V^\mu)^t \square \theta_{\mu\nu} K V^\nu + \frac{1}{2} (V^\mu)^t \eta_{\mu\nu} M^2 V^\nu, \quad (33)$$

where $(V^\mu)^t = \begin{pmatrix} \tilde{Z}^\mu & X^\mu \end{pmatrix}$, K is the matrix

$$K := \begin{pmatrix} 1 & -\chi_W \\ -\chi_W & 1 \end{pmatrix}. \quad (34)$$

The mass matrix M^2 is not diagonal

$$M^2 = \begin{pmatrix} \tilde{m}_Z^2 (1 + x^2) & \tilde{m}_Z m_X x \\ \tilde{m}_Z m_X x & m_X^2 \end{pmatrix}. \quad (35)$$

To diagonalize the Lagrangian (33) we make the orthogonal transformation $V \mapsto \tilde{V} = R V$, where $R^t R = 1$. Thus if we define the diagonal matrix as $K_D = R K R^t$, the eigenvalues of K_D are given by $\lambda_\pm = 1 \pm \chi_W$. Thereby the Lagrangian in terms of \tilde{V}^μ is

$$\mathcal{L}_{Gauge} = \frac{1}{2} (\tilde{V}^\mu)^t \square \theta_{\mu\nu} K_D \tilde{V}^\nu + \frac{1}{2} (\tilde{V}^\mu)^t \eta_{\mu\nu} \tilde{M}^2 \tilde{V}^\nu, \quad (36)$$

where $\tilde{M}^2 = R M^2 R^t$, and R is the rotation matrix of $SO(2)$ with angle of 45° . Now we redefine $\tilde{V} \rightarrow K_D^{1/2} \tilde{V}$, such that the mass matrix is $M_D^2 = (K_D^{1/2})^{-1} \tilde{M}^2 (K_D^{1/2})^{-1}$. Since M_D^2 is also symmetric and not diagonal, it can be diagonalized through an orthogonal matrix S , where $\tilde{V}^\mu = S \tilde{V}^\mu$, and we will end up with a fully diagonal Lagrangian, with $M_{diag}^2 = S M_D^2 S^T$. The eigenvalues of M_{diag}^2 are given by

$$\begin{aligned} M_Z &\simeq m_Z \left[1 + \frac{4u^2}{v^2} \sin^4 \theta_W \left(1 - \frac{8\chi}{\sqrt{2}} \right) \right], \\ M_X &\simeq m_X \left[1 - \frac{4u^2}{v^2} \sin^4 \theta_W \left(1 - \frac{8\chi}{\sqrt{2}} \right) \right]. \end{aligned} \quad (37)$$

Using the uncertainty of Z^0 mass, it fixes the scale VEV at $u \simeq 2.5$ GeV, and therefore, the mass of X^μ is $m_X \simeq 1.7$ GeV. The mass of the correspondent Higgs F is evaluated as $0.35 \text{ GeV} \lesssim M_F \lesssim 1 \text{ GeV}$. Under these conditions, if we use $|g_\zeta| = 0.15$, the mass of new fermion is around $m_\zeta = 266 \text{ MeV}$.

Another possibility, which seems more appealing, is to fix the scale u using the mass of $M_X = 17 \text{ MeV}$. Thereby, we obtain the VEV scale $u = 25 \text{ MeV}$, so the mass of Higgs- F is estimated in the range $3.5 \text{ MeV} \lesssim M_F \lesssim 10.6 \text{ MeV}$. In this range, the hidden ζ -fermion has a mass of $m_\zeta = 2.6 \text{ MeV}$.

To conclude this Letter, we would like to summarize that, by adopting an $SU(2) \times U(1) \times U(1)$ - type model, with two Higgs fields, we may set up to different scenarios : in a case, we get a TeV-scale gauge boson with mass around the 6 TeV, above the mass expected for the

so-called Z' -particle. On the other hand, changing the symmetry breaking pattern, our model may be describing the physics in the scale of the recently proposed X -boson associated with the 8Be^* -decay.

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